

WHAT IS CLAIMED IS

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1. A semiconductor light emitter,  
comprising:

a quantum well active layer which includes  
nitrogen and at least one other Group-V element; and

10 barrier layers which are provided  
alongside said quantum well active layer, wherein  
said quantum well active layer and said barrier  
layers together constitute an active layer,

wherein said barrier layers are formed of  
15 a Group-III-V mixed-crystal semiconductor that  
includes nitrogen and at least one other Group-V  
element, a nitrogen composition thereof being  
smaller than that of said quantum well active layer.

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2. The semiconductor light emitter as  
claimed in claim 1, wherein said barrier layers  
25 further include phosphorus.

5                 3. The semiconductor light emitter as  
claimed in claim 1, wherein said barrier layers are  
one of GaNAs, GaNPAs, GaInNAs, GaInNPAs, GaNAsSb,  
GaNPAsSb, GaInNAsSb, and GaInNPAsSb.

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4.         A         semiconductor         light         emitter,  
comprising:  
15                 a quantum well active layer which includes  
nitrogen and at least one other Group-V element;  
                   barrier         layers         which         are         provided  
alongside said quantum well active layer, wherein  
said quantum well active layer and said barrier  
20         layers together constitute one active layer;  
                   upper         and         lower         reflectors         which         are  
respectively provided on upper and lower sides of  
said one active layer, wherein said one active layer  
and said upper and lower reflectors together  
25         constitute a resonator structure;

a GaAs substrate on which said resonator structure is formed; and

spacer layers which are provided between said upper and lower reflectors and said one active  
5 layer,

wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes nitrogen and at least one other Group-V element, and said spacer layers are mainly formed of  
10 a material having a larger band gap than GaAs.

15 5. The semiconductor light emitter as claimed in claim 4, wherein said material having a larger band gap than GaAs is one of GaInPAs and AlGaAs.

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6. The semiconductor light emitter as claimed in claim 1, wherein said semiconductor light  
25 emitter is a surface emitting semiconductor laser.

5           7. The semiconductor light emitter as  
claimed in claim 4, wherein said semiconductor light  
emitter is a surface emitting semiconductor laser.

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8. An optical transmission module,  
comprising the semiconductor light emitter of claim  
6 serving as a light source.

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9. An optical transmission module,  
20 comprising the semiconductor light emitter of claim  
7 serving as a light source.

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10. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
6 serving as a light source.

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11. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
10 7 serving as a light source.

15 12. An optical communication system,  
comprising the semiconductor light emitter of claim  
6 serving as a light source.

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13. An optical communication system,  
comprising the semiconductor light emitter of claim  
7 serving as a light source.

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14. A method of making a semiconductor  
5 light emitter, said semiconductor light emitter  
including a quantum well active layer which includes  
nitrogen and at least one other Group-V element, and  
barrier layers which are provided alongside said  
quantum well active layer, wherein said quantum well  
10 active layer and said barrier layers together  
constitute an active layer, wherein said barrier  
layers are formed of a Group-III-V mixed-crystal  
semiconductor that includes nitrogen and at least  
one other Group-V element, a nitrogen composition  
15 thereof being smaller than that of said quantum well  
active layer, said method comprising the steps of:

providing a plurality of Ga raw material  
cells in a molecular beam epitaxy apparatus; and  
growing the quantum well active layer and  
20 the barrier layers by use of the respective Ga raw  
material cells, an amount of Ga supply of the cell  
used for growing the quantum well active layer being  
smaller than an amount of Ga supply of the cell used  
for growing the barrier layers.

15. A semiconductor light emitter,  
5 comprising:

a GaAs substrate; and  
an active region which is grown on said  
GaAs substrate, wherein said active region  
comprises:

10 a quantum well active layer which is made  
of a mixed-crystal semiconductor having a  
compressive strain and containing nitrogen and at  
least one other Group-V element; and

15 a strain-compensated layer which is  
situated alongside said quantum well active layer,  
and has a multi-layer structure that includes a  
first layer containing nitrogen and having a lower  
conduction band than GaAs and a second layer with a  
tensile strain including phosphorous and having a  
20 higher conduction band than GaAs, said first layer  
being situated closer to said quantum well active  
layer than said second layer.

16. The semiconductor light emitter as  
claimed in claim 15, wherein said quantum well  
active layer is a multiple quantum well active layer.

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17. The semiconductor light emitter as  
10 claimed in claim 15, wherein said first layer has a  
tensile strain relative to GaAs.

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18. The semiconductor light emitter as  
claimed in claim 15, wherein said quantum well  
active layer is a multiple quantum well active layer  
including a plurality of quantum well active layers  
20 and barrier layers between said quantum well active  
layers, said barrier layers including either  
phosphorous or nitrogen and having a tensile strain

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19. The semiconductor light emitter as  
claimed in claim 18, wherein the tensile strain of  
said second layer is larger than the tensile strain  
5 of said barrier layers.

10 20. The semiconductor light emitter as  
claimed in claim 15, wherein said multi-layer  
structure further includes an incremental-  
composition layer in which a strain continuously  
changes.

15

21. The semiconductor light emitter as  
20 claimed in claim 15, wherein said second layer is a  
GaAsP layer, and said first layer is a GaAsN layer,  
a GaAsP composition of said GaAsP layer being  $\text{GaAs}_{(1-x)}\text{P}_x$  ( $0 < x \leq 0.2$ ), and the GaAsN layer situated next  
said quantum well active layer having a thickness of  
25 1 nm or more.

5               22. The semiconductor light emitter as  
claimed in claim 15, wherein said semiconductor  
light emitter is a surface emitting semiconductor  
laser.

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23. An optical transmission module,  
comprising the semiconductor light emitter of claim  
15 15 serving as a light source.

20               24. An optical communication system,  
comprising the optical transmission module of claim  
23 serving as an optical transmission module.

25

25. A quantum well structure, comprising:  
a quantum well layer which includes In and  
nitrogen and at least one other Group-V element and  
5 has a compressive strain; and

barrier layers which are provided on upper  
and lower sides of said quantum well layer, wherein  
each of said barrier layers includes a layer  
including In and phosphorous and situated alongside  
10 said quantum well layer and a layer having a tensile  
strain.

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26. A semiconductor light emitter,  
comprising:

a quantum well layer which includes In and  
nitrogen and at least one other Group-V element and  
20 has a compressive strain; and

barrier layers which are provided on upper  
and lower sides of said quantum well layer, wherein  
said quantum well layer and said barrier layers  
together constitute a quantum well structure serving  
25 as an active layer, and each of said barrier layers

includes a layer including In and phosphorous and situated alongside said quantum well layer and a layer having a tensile strain.

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27. The semiconductor light emitter as claimed in claim 26, wherein the layer including In  
10 and phosphorous and situated alongside said quantum well layer has band gap energy that is lower than or equal to that of GaAs.

15

28. The semiconductor light emitter as claimed in claim 26, wherein the layer including In and phosphorous and situated alongside said quantum well layer has a strain of  $\pm 0.1\%$  or less.  
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25

29. The semiconductor light emitter as

claimed in claim 26, wherein each of said barrier layers includes an incremental composition layer.

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30. The semiconductor light emitter as claimed in claim 26, wherein the active layer has a multiple quantum well structure.

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31. The semiconductor light emitter as  
15 claimed in claim 26, wherein said semiconductor light emitter is a surface emitting semiconductor laser.

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32. The semiconductor light emitter as  
claimed in claim 26, wherein the layer including In  
and phosphorous and situated alongside said quantum  
25 well layer is made of GaInAsP.

5           33. An optical transmission module,  
comprising the semiconductor light emitter of claim  
26.

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34. An optical transmission system,  
comprising the optical transmission module of claim  
33.

15

35. A semiconductor light emitter,  
20 comprising:

      a GaAs substrate;  
      a quantum well active layer which includes  
      nitrogen and at least one other Group-V element, and  
      has a compressive strain relative to said GaAs  
25 substrate; and

barrier layers which are provided alongside said quantum well active layer, wherein said quantum well active layer and said barrier layers together constitute an active layer,

5           wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes antimony, and said quantum well active layer does not include antimony.

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36. The semiconductor light emitter as claimed in claim 35, wherein said barrier layers  
15 further include nitrogen.

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37. A semiconductor light emitter,  
comprising:

a GaAs substrate;  
a quantum well active layer which includes nitrogen and at least one other Group-V element, and  
25 has a compressive strain relative to said GaAs

substrate; and

barrier layers which are provided alongside said quantum well active layer, wherein said quantum well active layer and said barrier 5 layers together constitute an active layer,

wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes antimony and nitrogen, and said quantum well active layer has no or some concentration of 10 antimony smaller than an antimony concentration of said barrier layers and has an nitrogen concentration larger than that of said barrier layers.

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38. The semiconductor light emitter as claimed in claim 35, wherein said barrier layers are 20 formed of GaAsSb, GaNAsSb, GaInNAsSb, GaNPAsSb, GaPAsSb, GaInNPAsSb, GaInPAsSb, or GaInAsSb.

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39. The semiconductor light emitter as  
claimed in claim 37, wherein said barrier layers are  
formed of GaAssSb, GaNAssSb, GaInNAssSb, GaNPAssSb,  
GaPAssSb, GaInNPAssSb, GaInPAssSb, or GaInAsSb.

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40. The semiconductor light emitter as  
10 claimed in claim 35, wherein said barrier layers  
including antimony have a tensile strain relative to  
said GaAs substrate.

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41. The semiconductor light emitter as  
claimed in claim 37, wherein said barrier layers  
including antimony have a tensile strain relative to  
20 said GaAs substrate.

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42. A semiconductor light emitter,

comprising:

a GaAs substrate;

a quantum well active layer which includes nitrogen and at least one other Group-V element, and

5 has a compressive strain relative to said GaAs substrate;

barrier layers which are provided around said quantum well active layer; and

an intermediate layer which is provided

10 between said quantum well active layer and said barrier layers, and is formed of a Group-III-V mixed-crystal semiconductor that includes antimony.

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43. The semiconductor light emitter as claimed in claim 42, wherein said intermediate layer is formed of GaAsSb, GaNAsSb, GaInNAsSb, GaNPAsSb,

20 GaPAsSb, GaInNPAsSb, GaInPAsSb, or GaInAsSb.

25

44. The semiconductor light emitter as

claimed in claim 42, wherein said barrier layers have a tensile strain relative to said GaAs substrate, and said intermediate layer including antimony has a lattice constant that is larger than 5 that of said barrier layers and smaller than that of said quantum well active layer.

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45. A semiconductor light emitter, comprising a quantum well active layer which includes nitrogen and at least one other Group-V element, wherein said quantum well active layer is 15 comprised of first layers and second layers stacked one over the other in cyclic arrangement, said first layers including In, Sb, and at least one other Group-V element, and said second layers including no or some In composition smaller than that of the 20 first layers, N, and at least one other Group-V element.

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46. The semiconductor light emitter as claimed in claim 45, wherein said first layers are GaInAsSb, and said second layers are GaNAs.

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47. A method of producing the semiconductor light emitter as claimed in claim 35,  
10 wherein at least the active layer is formed through crystal growth by an MOCVD method.

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48. The semiconductor light emitter as claimed in claim 35, wherein said semiconductor light emitter is a surface emitting semiconductor layer.

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49. An optical transmission module,  
25 comprising the semiconductor light emitter of claim

48 serving as a light source.

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50. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
48 serving as a light source.

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51. An optical communication system,  
comprising the semiconductor light emitter of claim  
15 48 serving as a light source.

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52. A method of producing the  
semiconductor light emitter as claimed in claim 37,  
wherein at least the active layer is formed through  
crystal growth by an MOCVD method.

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53. The semiconductor light emitter as  
claimed in claim 37, wherein said semiconductor  
5 light emitter is a surface emitting semiconductor  
layer.

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54. An optical transmission module,  
comprising the semiconductor light emitter of claim  
53 serving as a light source.

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55. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
20 53 serving as a light source.

25

56. An optical communication system,

comprising the semiconductor light emitter of claim  
53 serving as a light source.

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57. A method of producing the  
semiconductor light emitter as claimed in claim 42,  
wherein at least the active layer is formed through  
10 crystal growth by an MOCVD method.

15 58. The semiconductor light emitter as  
claimed in claim 42, wherein said semiconductor  
light emitter is a surface emitting semiconductor  
layer.

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25 59. An optical transmission module,  
comprising the semiconductor light emitter of claim  
58 serving as a light source.

5               60. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
58 serving as a light source.

10

61. An optical communication system,  
comprising the semiconductor light emitter of claim  
58 serving as a light source.

15

62. A semiconductor light emitter,  
20 comprising:  
                  a GaAs substrate;  
                  a quantum well active layer which includes  
                  nitrogen and at least one other Group-V element, and  
                  has a compressive strain relative to said GaAs  
25 substrate; and

barrier layers which are provided alongside said quantum well active layer, wherein said quantum well active layer and said barrier layers together constitute an active layer,

5               wherein said barrier layers are formed of a Group-III-V mixed-crystal semiconductor that includes both phosphorous and antimony.

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63. The semiconductor light emitter as claimed in claim 62, wherein said barrier layers further include nitrogen.

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64. The semiconductor light emitter as 20 claimed in claim 62, wherein said barrier layers are GaNPAsSb, GaPAsSb, GaInNPAsSb, or GaInPAsSb.

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65. A semiconductor light emitter,  
comprising:

a GaAs substrate;

a quantum well active layer which includes  
5 Ga, As, and Sb, and has a compressive strain  
relative to said GaAs substrate; and

barrier layers which are provided  
alongside said quantum well active layer, wherein  
said quantum well active layer and said barrier  
10 layers together constitute an active layer,

wherein said barrier layers are formed of  
a Group-III-V mixed-crystal semiconductor that  
includes both phosphorous and antimony.

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66. The semiconductor light emitter as  
claimed in claim 65, wherein said barrier layers are  
20 GaPAsSb, AlGaPAsSb, GaInPAsSb, or AlGaInPAsSb.

25

67. The semiconductor light emitter as

claimed in claim 62, wherein said quantum well active layer is a multiple quantum well active layer.

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68. The semiconductor light emitter as claimed in claim 65, wherein said quantum well active layer is a multiple quantum well active layer.

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69. The semiconductor light emitter as  
15 claimed in claim 62, wherein said semiconductor light emitter is a surface emitting semiconductor laser.

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70. The semiconductor light emitter as  
claimed in claim 65, wherein said semiconductor light emitter is a surface emitting semiconductor  
25 laser.

5           71. An optical transmission module,  
comprising the semiconductor light emitter of claim  
69 serving as a light source.

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72. An optical transmission module,  
comprising the semiconductor light emitter of claim  
70 serving as a light source.

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73. An optical transceiver module,  
20 comprising the semiconductor light emitter of claim  
69 serving as a light source.

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74. An optical transceiver module,  
comprising the semiconductor light emitter of claim  
70 serving as a light source.

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75. An optical communication system,  
comprising the semiconductor light emitter of claim  
10 69 serving as a light source.

15 76. An optical communication system,  
comprising the semiconductor light emitter of claim  
70 serving as a light source.

20

77. A semiconductor laser, comprising:  
well layers; and  
barrier layers, wherein said well layers  
25 and said barrier layers are stacked one over the

other to form an active layer having a multiple quantum well structure, said barrier layers being made of a mixed-crystal semiconductor including nitrogen and at least one other Group-V element,  
5 said barrier layers including p-type impurity doped at concentration ranging from  $1 \times 10^{17}$  cm $^{-3}$  to  $1 \times 10^{19}$  cm $^{-3}$ .

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78. The semiconductor laser as claimed in claim 77, wherein the p-type impurity is carbon.

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79. The semiconductor laser as claimed in claim 77, wherein a doping concentration of the p-  
20 type impurity in one of said barrier layers is lower in a region adjoining one of said well layers than in a region separated from said well layers.

25

80. The semiconductor laser as claimed in  
claim 77, wherein said well layers and said barrier  
layers have opposite strains.

5

81. The semiconductor laser as claimed in  
10 claim 77, wherein said well layers are made of a  
mixed-crystal semiconductor including nitrogen and  
at least one other Group-V element.

15

82. The semiconductor laser as claimed in  
claim 77, further comprising a resonator structure  
having a pair of multi-layered reflectors at  
20 opposite ends, said resonator structure including  
said active layer, and said semiconductor laser  
being a surface emitting semiconductor laser.

25

83. A method of making the semiconductor  
laser of claim 77, comprising a step of doping  
carbon in the barrier layers by use of an organic  
5 nitrogen raw material.

10 84. An optical transmission module,  
comprising the semiconductor laser of claim 77.

15 85. An optical transmission system,  
comprising the optical transmission module of claim  
84.

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